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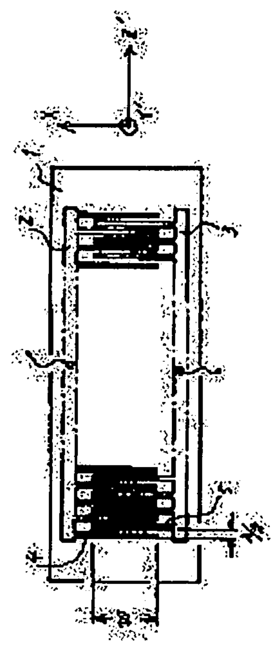
(54) SLIP WAVE RESONATOR

(57)Abstract:
PURPOSE: To obtain an inexpensive resonator which has the excellent temperature characteristics and is insensitive to the contaimination on the surface, by setting the thickness of film at a prescribed value for a multipair interdigital transducer electrode provided on a quartz substrate that transmits the slip wave.
CONSTITUTION: The rotary Y-cut angle is set counterclockwise in a range of $-43°\sim-52°$ in terms of the axis X for a quartz substrate which transmits the slip wave. The bus bar electrodes 2 and 3 are formed with Al on the substrate 1 in the direction of the axis Z'. These electrodes are so extended as to cross interdigital electrode fingers 4 and 5 alternately. The ratio h/λ betwen the film thickness (h) of the extended electrode and the propagating slip wavelength λ is regulated to $\geq 2\%$, and the number of pairs of electrodes 4 and 5 is regulated to 800 ± 200. At the same time, the w/λ ratio is regulated to $8\sim 15$ between the cross length (w) of the electrode finger and the wavelength λ. As a result, the right-under-electrode enclosing effect is improved for the oscillating energy of the slip wave along with excellent temperature characteristics. Thus an inexpensive resonator, which is insensitive to the surface contamination and the aging and oscillates the high frequency up to about 1GHz with the basic wave and with virtually no spuriousness and high Q.



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54すべり波共振器

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明　細　書

1.発明の名称

すべり波共振器

2.特許請求の範囲

(1) すべり波を伝搬せしめる水晶基板の主表面上に多対のインタディジタル・トランスジューサ電極を設けて該電極に印加された電気エネルギをすべり波に変換するすべり波共振器に於いて、前記水晶基板を回転Yカット，カット・アングル－43°乃至－52°、すべり波伝搬方向をZ′軸方向とすると共に、前記水晶基板上に設ける多対インタディジタル・トランスジューサ電極をAlにて構成しかつその膜厚を伝搬するすべり波々長の2.0％以上とすることによってすべり波の振動エネルギの前記電極直下への閉じ込め効率を向上したことを特徴とするすべり波共振器。

(2) 前記インタディジタル・トランスジューサ電極の電極対数を800±200とすることにより共振器の容量比と副共振レベルを低レベルに保ちつつ高いQを得ることを特徴とする特許請求の範囲1記載のすべり波共振器。

(3) 前記インタディジタル・トランスジューサ電極の電極指交叉長を前記電極によって励起されるすべり波々長の8乃至15倍とすることにより共振器の容量比を低レベルに保ちつつ高いQを得ることを特徴とする特許請求の範囲1又は2記載のすべり波共振器。

3.発明の詳細な説明

本発明は一般にSSBW（Surface Skimming Bulk Wave）等と呼ばれている圧電基板の表面直下を伝搬する波動（斯る種類の波動の総称を本発明の明細書に於いてはすべり波と称する）をインタディジタル・トランスジューサ電極によって励起せしめ、その振動エネルギを前記電極直下に閉じ込めるタイプの共振器に関する。

従来、安定した高周波を得るには殆んどの場合水晶薄板の厚みすべり振動を利用していたが、その最高周波数は水晶基板の厚さに依存する為基本波で40MHz程度が限界であって更に高

い周波数を得るには通常基本波周波のオーバートーン振動を利用していた。しかしながらオーバートーン次数は9次程度までが使用しうる限界であり、該次数が高くなると所謂容量比γが該次数の自乗に比例して悪化し且つインピーダンスも上昇するので回路とのマッチングが困難となる等の問題を生ずるものであった。

上述の如き問題を解決する一手段として最近、インタディジタル・トランスジューサ電極によって弾性表面波を発生させ、これを利用する共振器の研究と実用化が盛んであるが、これは数十M乃至1GHz程度までの高周波を基本波周波にて励振しうるものである。

しかしながら弾性表面波共振器は励振された波動が圧電基板表面を伝搬する為、基板表面の汚染或はエージングによる表面状態の変化の影響を強くうけるという欠陥があるのみならず周波数ー温度特性についても需要者を充分満足させるものではなく、更に優れた特性が要求されている。

本発明は以上説明した如き既存の共振器の持つ欠陥或は問題点を除去する為になされたものであって、弾性表面波共振器と同等の高い周波数を基本波にて励振でき、且つその波動が圧電基板の表面直下を伝搬するすべり波を利用して数十M乃至1GHz程度の周波数帯での使用に適した表面汚染に強くエージング特性，温度特性に優れ、且つスプリアスの極めて少ない共振器を提供することを目的とする。

以下、本発明をこれをなすに至った理論的考察と実験結果とに基づいて詳細に説明する。

圧電基板表面直下を伝搬するすべり波の存在及び多対のインタディジタル・トランスジューサ電極によってこの波を励起しうることは従前より知られていたが、これを共振器に応用する試みについては殆んど研究がなされていなかった。その理由は弾性表面波共振器からの類推によってすべり波々長の1％以下の膜厚のインタディジタル・トランスジューサ電極を設けたすべり波共振器は発振条件を満足することが困難であった上、発振してもそのQが極めて低くとうてい実用に耐えるものではなかったからである。

一方、本発明の発明者等は既に出願した弾性表面波共振器に関する一連の特許出願，特願昭56－56710等に於いて水晶基板表面に極めて膜厚の大なる（表面波々長の1.5％以上）インタディジタル・トランスジューサ電極を設けることによって少数の電極指対数によって充分大なるQを有しかつ副共振の少ない小型の共振器を得ることができることを示し、その理由は表面波に対する電極指膜厚の反射効果、質量付加効果による表面波振動エネルギの閉じ込め効果の強調及び電極指断面積の増大による等価抵抗の減少によるものであろうと推論した。

この推論をすべり波に援用して、すべり波を励起するインタディジタル・トランスジューサ電極膜厚を著しく大きくするならば圧電基板表面が振動しないすべり波に対しては前記反射効果は考えにくいが、質量付加効果及び等価抵抗減少の効果を期待し得るであろう。

本発明は以上の如き推定に基づいてなされたものであり、電極膜厚を一定以上厚くした場合に実用性のある充分に高いQを得ることが確認された。

以下本発明の基礎となった実験結果について詳細に説明する。

第1図は本実験に使用したすべり波共振器の構成を示す図である。

先ず圧電基板1としては温度特性を考慮して水晶の回転Yカット，切断角をX軸に関して反時計廻りに－43°～－52°の範囲のものを使用した。この切断角を有する水晶基板を用いるならばすべり波伝搬速度は同じ回転Yカット水晶基板の弾性表面波伝搬速度に比してわずか数％高速であるにすぎないが温度－周波数特性は三次曲線となり極めて温度特性の良好なものとなる。

因みに前記切断角を35°～42°の範囲に選べば温度特性は劣化するがすべり波伝搬速度は

前記弾性表面波伝搬速度の約1.6倍となる。

さて上記の如き水晶基板1上にAlを用いてZ軸方向にバスバー電極2，3を設け、両者から交互に多数のインタディジタル電極指4，4……及び5，5，……を交叉する如く延長する。これは周知の如く蒸着したAlに対しマスクを介してフォト・エッチングにより形成するものである。又前記インタディジタル・トランスジューサ電極指4又は5の各々とこれに隣接する無電極部との合計幅はすべり波々長λの半分となるようにし、両者の幅比は製造の容易さから1：1に構成するのが一般的である。

更に前記インタディジタル電極指4，4，……及び5，5……のオーバーラップ幅を交叉長wと称し、この値を変化することによって共振器の諸特性を制御することができる。

以上の如き形状のインタディジタル・トランスジューサ電極は少なくとも弾性表面波共振器を構成する上では表面波反射用すだれ状金属或は溝又は孔を備えた共振器に比して構成単純で製造性が良好な上不要な副共振や他との音響的結合が少なく優れた特性を有するものであるが、すべり波共振器に於いても同様の効果があると考えられる。

以上の如きインタディジタル・トランスジューサ電極を設けた共振器を用いて行った実験結果について説明するに、先ず電極対数Nを800対、前記交叉長wをすべり波々長λで規準化したw／λの値を10に固定し、Al電極の膜厚h／λを変化させた場合の共振器の挙動を第2図(a)の等価回路を仮定してアドミタンス・チャートを用いて検討した結果第2図(b)～(e)を得た。本チャートから明らかな如く電極膜厚h／λが殆ど2％以下の場合、本すべり波共振器の特性はチャート上誘導性領域が存在せずハートレー又はコルピッツ型水晶発振回路に挿入しても発振し得ないことが判明した。

さてそこで各種電極膜厚を有するすべり波共振器についてそのQと副共振レベルを調べた結果を第3図に示す。

本図に於いて電極膜厚h／λが増大するに従いQ及び副共振レベルも増大し、h／λが4％近傍に於いてQは飽和し、副共振レベルは急増する如く見える。

一方、電極膜厚h／λを固定した上で電極対数Nを変化させた場合、Q，副共振レベル及びrがいかに変化するかを調べた結果を第4図に示す。

本図から明らかな如く電極対数Nが多い程Qは増加するが、r及び副共振レベルも800対前後を境に増大する傾向を示す。

従って共振器としての望ましい構成としては、要求される仕様にもよるが一般的には水晶基板を使用する限り電極対数Nが800±200，電極膜厚h／λは0.025乃至0.03程度であることが判る。

又、副共振レベルは電極対数Nに対しては電極膜厚h／λの減少に従ってわずかに平行移動的に減少し一方rは電極膜厚h／λの減少に従ってわずかに平行移動的に増大する傾向が見られたが図面の繁雑を避ける為省略した。

尚、更に前記交叉長w／λについて調べた結果を第5図に示す。本図から明らかな如く交叉長w／λにも最適値がある如く見え、その範囲は概ね8乃至15の間に存し、交叉長w／λを変化させることによって得られるQ又はrの変化は電極膜厚h／λ或は電極対数Nを変化することによる共振器特性の変化に比べればわずかでありその重要性は二次的であるといえる。

以上説明した実験の結果は共振器を空気中で共振させたものであるが弾性表面波共振器にあっては真空中に於いて共振する共振器のQは空気中のそれに比べて15乃至30％改善されることが知られている。この知見をすべり波共振器に援用した結果弾性表面波共振器の場合程の効果はなかったが約5％程度のQの向上がみられた。

以上の実験結果からすべり波共振器に於いても共振器の特性を左右する最も重要な構成要素はその電極膜厚h／λであり、他の要素、例え

ば電極対数Nは電極膜厚h／λとは殆んど無関係にr或は副共振のレベルから一定の値に帰着せざるを得ず、又前記交叉長w／λも共振器特性に影響を与えるその最適値が存在する~~こと~~がその効果は二次的なものであることが明らかとなった。

以上本発明の共振器に関する実験の結果について説明したが、電極材料としてAl以外の例えばAu，Ag，Cr又はNi等について言及していなかったのでこれらについて簡単に説明する。

前述の電極の質量効果が振動エネルギ閉じ込め効果を強調するものであるとすればAlよりはるかに密度の大きな金属材料によって電極を構成し、その膜厚をAlの密度との割合いに比例して薄くしても同様の効果がありそうに思われたがAu，Cr及びNiについて実験した結果は全く予想に反するものであってQは上昇せずスプリアスも多くなるという結果を得た。

この理由は目下のところ不明であるが、弾性表面波共振器の場合にも同様の結果がより顕著に現出していることからして、水晶基板直下を伝搬するすべり波も水晶基板と電極との境界近傍に於いて両者の音響インピーダンスの差に起因する振動の影響を受けると同時に前記両インピーダンスの差が大きすぎることがすべり波の伝搬及び振動エネルギの閉じ込め効果を悪化させる方向に働いているものと考えざるを得ない。

従って現状に於いては基板の水晶と音響インピーダンスが近似するAlを電極材料として用いるのが最も良い。

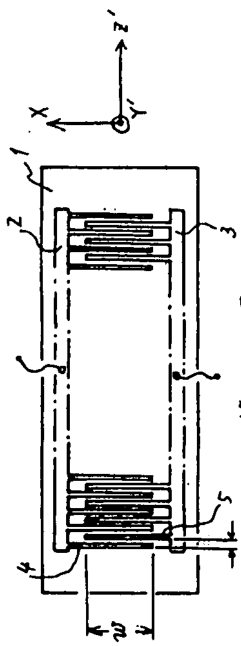
本発明は以上説明した如く構成するので極めて温度特性良好にしてスプリアスが殆んどなく表面汚染及びエージングに対し鈍感でありしかも1GHz程度までの高周波を基本波にて発振する共振器を安価に得ることが可能となる為、近年益々使用周波数帯が高くなっている電子機器の要求に容易に応ずることができ、しかもこれら機器の小型化，高安定化に著しい効果を発揮するものである。

4.図面の簡単な説明

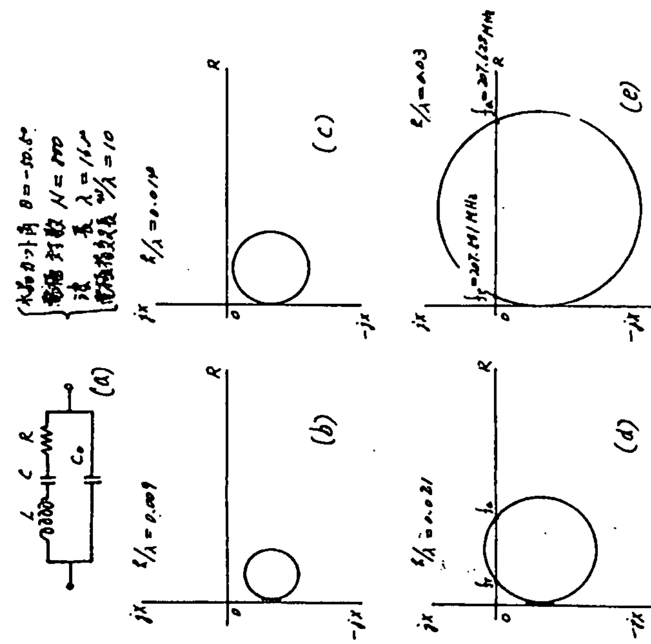
第1図は本発明のすべり波共振器の電極構成を示す図、第2図(a)は第1図のすべり波共振器の等価回路、同図(b)~~及~~乃至(e)は夫々電極膜厚をすべり波々長の0.9％，1.4％，2.1％及び~~3.7~~3.0％の場合のアドミタンス・チャートの図、第3図はすべり波共振器の電極指対数を固定した場合、電極膜厚の変化に対するQ及び副共振レベルの変動の実験結果を示す図、第4図は各電極膜厚に対し電極指対数を変化した場合のQ，r及び副共振レベルの変動の実験結果を示す図、第5図は電極指交叉長~~を~~の変化に対するQ及びrの変動を示す実験結果の図である。

1……水晶基板，　4，5……インタディジタル・トランスジューサ電極

特許出願人　　東洋通信機株式会社



第1図



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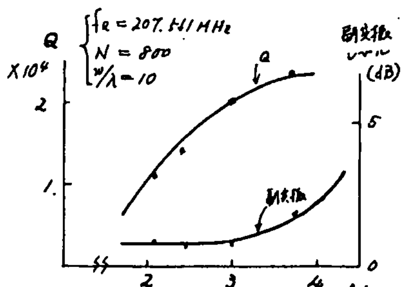
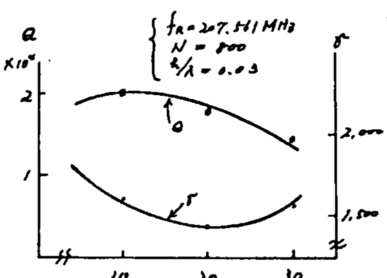
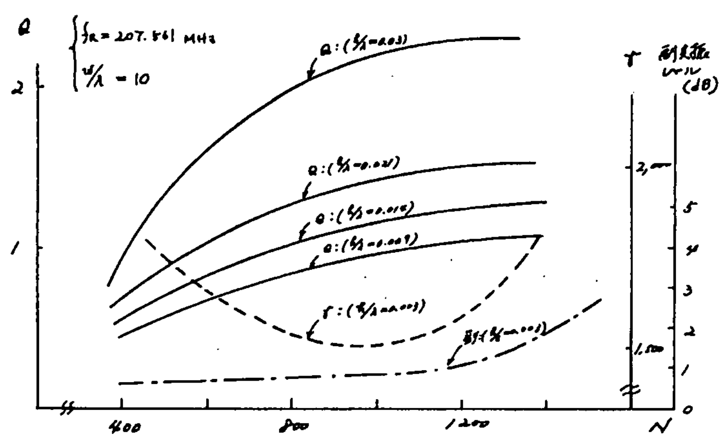


第3図



第5図



第5図

手 続 補 正 書

昭和57年 1 月29日

特許庁 長 官 殿

1．事 件 の 表 示

昭和56年 特 許 願第131739 号

2．発 明 の 名 称 すべり波共振器

3．補 正 を す る 者

事件との関係 特許出願人

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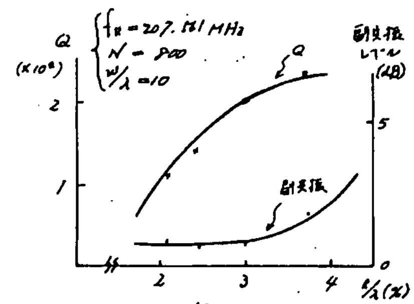
代表取締役 鈴 木 康 夫

4．手続補正指令書の日付 昭和57年1 月5 日

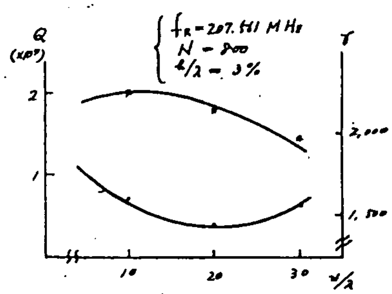
5．補正により増加する発明の数 なし

6．補 正 の 対 象 図面

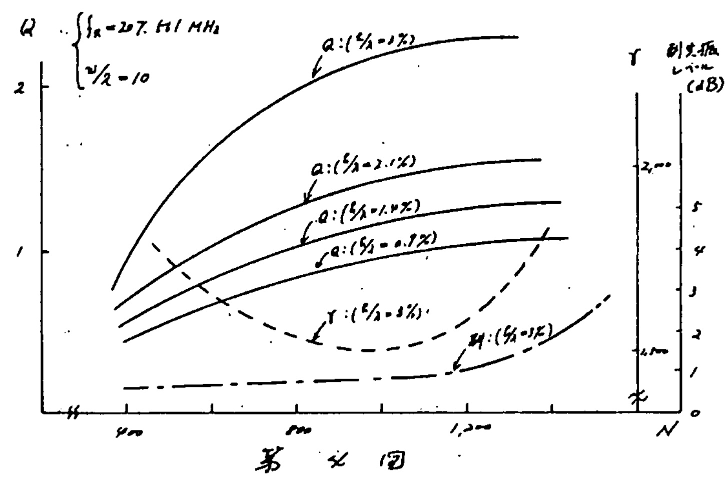
7．補 正 の 内 容 添付別紙の通り.



第 3 図



第 5 図



第 4 図

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(54) Shear Wave Resonator

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SPECIFICATION

1. Title of the Invention

Shear Wave Resonator

2. Claims

(1) A shear wave resonator, comprising:

a crystal substrate propagating a shear wave; and

multiple pairs of inter-digital transducer electrodes provided on the crystal substrate and receiving electric energy that is converted into the shear wave, wherein

the crystal substrate is a rotation Y-cut of which a cut angle is set to be from -43° to -52° and propagates the shear wave in Z'-axis direction, and

the multiple pairs of inter-digital transducer electrodes are made of Al and a film thickness thereof is set to be 2.0% or more of a wavelength of the shear wave that is propagated so as to improve an effect of confining vibration energy directly beneath the electrodes.

(2) The shear wave resonator according to Claim 1, wherein number of pairs of the inter-digital transducer electrodes is set to be 800±200 so as to obtain a high Q while maintaining a capacitance ratio and a sub-resonance level of the

resonator to be low.

(3) The shear wave resonator according to Claim 1 or 2, wherein an aperture length of electrode fingers of the inter-digital transducer electrodes is set to be 8 to 15 times as large as a wavelength of the shear wave excited with the electrodes so as to obtain the high Q while maintaining the capacitance ratio and the sub-resonance level of the resonator to be low.

3. Detailed Description of the Invention

The present invention is related to a resonator exciting a wave that propagates directly beneath a surface of a piezoelectric substrate with inter-digital transducer electrodes, and confining vibration energy directly beneath the electrodes. The wave is generally called surface skimming bulk wave (SSBW), for example, (an inclusive term of waves of this kind is referred to as a "shear wave" in the specification of the present invention).

In order to obtain a stable high frequency wave, thickness shear vibration of a crystal thin plate has been conventionally used in most cases. However, the highest frequency depends on a thickness of the crystal substrate, so that the frequency is limited to 40 MHz at a fundamental wave. Therefore, in order to obtain a higher frequency, overtone vibration of the fundamental frequency has been usually employed. However, the applicable limit of the overtone order is up until about ninth order. If the order is increased, so-called capacitance ratio γ deteriorates in proportion to the square of the order and impedance increases, causing problems such as difficulty in matching with a circuit.

As one means of solving the above problems, a resonator that generates a surface acoustic wave with the inter-digital transducer electrodes and uses it has

been widely studied and made practicable recently. This can vibrate with high frequency from about tens of M to 1GHz as a fundamental wave frequency.

However, the wave that is excited propagates on the surface of the piezoelectric substrate, so that a surface acoustic wave resonator has not only a defect that it is strongly affected by contamination of the surface of the substrate or variation of the surface state due to aging, but also has a defect that frequency and temperature properties do not sufficiently satisfy consumers. Therefore, further superior properties to avoid the above defects have been demanded.

The present invention is intended to eliminate the defects or problems of existing resonators such as the one described above and provide a resonator that is resistant to the surface contamination and has excellent aging and temperature properties and little unwanted mode. The resonator can vibrate with high frequency, comparably to the surface acoustic wave resonator, as a fundamental wave and is suitable for being used within a frequency band from about tens of M to 1GHz by the use of the shear wave that propagates directly beneath the piezoelectric substrate.

Hereinafter, the present invention will be described in detail based on theoretical speculation and an experimental result.

It has been conventionally known that the shear wave which propagates directly beneath the surface of the piezoelectric substrate exists and the wave can be excited with the multiple pairs of inter-digital transducer electrodes, but an attempt to apply this to resonators has been rarely studied. The reason of it comes from analogical inference from the surface acoustic wave resonator and is such that it is very difficult for the shear wave resonator including the inter-digital transducer

electrodes having a film thickness that is 1% or less of wavelength of the shear-wave to satisfy oscillating conditions, and even if it oscillates, the Q is very low to be far from actual use.

On the other hand, inventors of the present invention have disclosed that inter-digital transducer electrodes having substantially large film thickness (1.5 % or more of the wavelength of the surface wave) are provided on a surface of a crystal substrate so as to be able to obtain a small resonator having sufficiently large Q with small number of pairs of electrode fingers and small sub-resonance and the inventors have deduced reasons of this, in series of patent applications such as Application No. 56-56710, that have been already filed and are related to surface acoustic wave resonators. The reasons that the inventors deduced are a reflection effect due to the film thickness of the electrode fingers with respect to the surface wave; an emphasis of a confining effect for surface wave vibration energy due to a mass addition effect; and reduction of equivalent resistance due to an increase of the sectional area of the electrode fingers.

If this deduction is applied to the shear wave so as to highly increase the film thickness of the inter-digital transducer electrodes that excite the shear wave, the mass addition effect and the effect of the decrease of the equivalent resistance can be expected, though the reflection effect is hardly expected with respect to the shear wave with which the surface of the piezoelectric substrate does not vibrate.

The present invention is based on the deduction as above. It was confirmed that a sufficiently high Q for a practical use was obtained in a case where the film thickness of the electrodes is made thick above a certain level.

The experimental result that was a base of the present invention will now be

described in detail.

Fig. 1 is a figure showing a structure of the shear wave resonator used in the experimentation.

First, as a piezoelectric substrate 1, a rotation Y-cut crystal of which a cut angle is in a range from -43° to -52° counterclockwise with respect to X-axis was used in consideration of the temperature property. If a crystal substrate having this cut angle is used, the temperature and frequency properties shows a cubic curve to be substantially preferable, though a propagation velocity of the shear wave is higher only a few percent than a propagation velocity of the surface acoustic wave of the same rotation Y-cut crystal plate.

Incidentally, if the cut angle is set in a range from 35° to 42°, the propagation velocity of the shear wave becomes 1.6 times as high as the propagation velocity of the surface acoustic wave, though the temperature property degrades.

Here, bus bar electrodes 2, 3 are provided on the crystal substrate 1 described above with Al in Z-axis direction, and respectively from these, multiple inter-digital electrode fingers 4, 4, ··· and 5, 5, ··· are extended alternately with each other. These are formed, as is widely known, such that Al which is vapor-deposited is subject to photo-etching through a mask. In addition, the total width of each of the inter-digital transducer electrode fingers 4, or 5 and a non-electrode area is set to be half of a wavelength λ of the shear wave and a width ratio of these is generally set to be 1:1 due to the ease of manufacture.

Further, a width in which the inter-digital electrode fingers 4, 4, ··· overlap the inter-digital electrode fingers 5, 5, ··· is called an aperture length w. This value is varied, so that properties of the resonator can be controlled.

The structure of the inter-digital transducer electrodes having such shape is simpler than a resonator including an inter-digital metal, groove, or hole for surface acoustic wave reflection so as to have favorable productivity in terms of at least a constitution of the surface acoustic wave resonator. In addition, the inter-digital transducer electrodes have little unnecessary sub-resonance and acoustic coupling with others so as to have excellent property. It is presumable that the similar advantageous effects are shown also in the shear wave resonator.

The result of the experimentation using the resonator including the inter-digital transducer electrodes mentioned above will be described. The result shown in Figs. 2(b) to (e) was obtained by studying a behavior of the resonator while using an admittance chart based on a premise of an equivalent circuit of Fig. 2(a). The resonator was in a condition where the number N of pairs of electrodes was 800 pairs; a w / λ value obtained by standardizing the aperture length w by the wavelength λ of the shear wave was fixed to be 10; and the film thickness h / λ of the Al electrode is varied. As is apparent from the chart, it became clear that in a case where the film thickness h / λ of the electrodes is approximately 2% or less, there is no inductive area on the chart as the property of the shear wave resonator, so that the resonator does not possibly oscillate even if it is inserted into a Hartley or Colpitts crystal oscillating circuit.

Fig. 3 shows a result obtained by studying a Q and a sub-resonance level according to a shear wave resonator having various film thicknesses of electrodes.

In this figure, as the film thickness h / λ of the electrodes increases, the Q and the sub-resonance level increase as well. It seems that when the h / λ is near 4%, the Q is saturated and the sub-resonance level sharply increases.

On the other hand, Fig. 4 shows a result obtained by studying how the Q, the sub-resonance level, and a γ vary in a case where the film thickness h / λ of the electrodes is fixed and the number N of pairs of electrodes is changed.

As is apparent from this figure, as the number N of pairs of the electrodes increases, the Q increases, and the γ and the sub-resonance level also show a tendency of increase across around 800 pairs.

Consequently, it became clear that as long as a crystal substrate is used, a preferable structure of the resonator is generally such that the number N of pairs of the electrodes is 800 ± 200 and the film thickness h / λ of the electrodes is about from 0.025 to 0.03, though they depend on a specification that is demanded.

There was such a tendency that the sub-resonance level slightly decreases like parallel shift with respect to the number N of pairs of the electrodes in accordance with the decrease of the film thickness h / λ of the electrodes, while the γ slightly increases like parallel shift in accordance with the decrease of the film thickness h / λ of the electrodes, but it is omitted in order to avoid complication of the figure.

Here, Fig. 5 shows a result obtained by studying the aperture length w / λ. As is apparent from this figure, it seems that the aperture length w / λ also has an optimum value and its range is between about 8 and 15. The variation of the Q or the γ obtained by changing the aperture length w / λ is smaller than the variation of the resonator property by changing the film thickness h / λ of the electrodes or the number N of pairs of the electrodes, thereby being able to be said that the importance thereof is secondary.

The experimental results described above were obtained such that the resonator was vibrated in the air. According to the surface acoustic wave resonator, it is

known that the Q of the resonator that vibrates in vacuum is improved about 15 to 30% compared to that in the air. The application of this knowledge to the shear wave resonator results in the Q increasing about 5%, though there was an effect as large as the case of the surface acoustic wave resonator.

From the above results, it became clear that the most important structural element that affects the property of the resonator is the film thickness h / λ of the electrodes, also in the shear wave resonator. Other elements, for example, the number N of pairs of the electrodes hardly avoids to reach a certain value, almost irrelevantly to the film thickness h / λ of the electrodes, due to the γ or the sub-resonance level. In addition, the aperture length w / λ has the optimum value that affects the property of the resonator, but the effect is secondary.

The experimental results according to the resonator of the present invention have been described above. However, Au, Ag, Cr, and Ni, for example, have not been referred as a material of the electrodes other than Al, so that these will be described briefly.

If the mass effect of the electrodes described above emphasizes the energy confining effect, it seemed that the same effects could be obtained in a case where the electrodes are made of metal material having greatly larger density than that of Al and the film thickness thereof is made thin in proportion to the ratio with respect to the density of Al. However, the result of the experimentation on Au, Cr, and Ni was contrary to expectations such that the Q did not increase and the unwanted mode increased.

The reason of this is unclear at present, but the similar result was further prominently revealed also in a case of the surface acoustic wave resonator.

Therefore, it should be considered that the shear wave propagating directly beneath the crystal substrate is also affected by the vibration caused by a difference between acoustic impedances of the crystal substrate and the electrodes near the border of them, and too large difference between the impedances deteriorates the propagation of the shear wave and the confining effect of the vibration energy.

Consequently, it is most preferable to use Al, of which the acoustic impedance approximates that of the crystal substrate, as the material of the electrodes.

The present invention is structured as described above, so that it becomes possible to obtain such resonator at low cost that has very favorable temperature property, has little unwanted mode, is insensitive to the surface contamination and aging, and oscillates with high frequency up to about 1 GHz as a fundamental frequency. Therefore, it can meet the demand for electronic equipments of which an operating frequency band has been more and more increased in recent years, and it yields very substantial benefits for miniaturization and high stabilization of these equipments.

4. Brief Description of the Drawings

Fig. 1 is a diagram showing a structure of electrodes of a shear wave resonator according to the present invention. Fig. 2(a) is a diagram showing an equivalent circuit of the shear wave resonator of Fig. 1. Figs. 2(b) to (e) are admittance charts respectively showing cases where film thicknesses of the electrodes are respectively 0.9%, 1.4%, 2.1%, and 3.0% of a wavelength of a shear wave. Fig. 3 is a diagram of an experimental result showing variation of a Q and a sub-resonance level in a case where the number of pairs of electrode fingers of the shear wave resonator is fixed.

Fig. 4 is a diagram of an experimental result showing variation of a Q, a γ, and a sub-resonance level in a case where the number of pairs of electrode fingers of the shear wave resonator is changed versus a film thickness of each of the electrodes. Fig. 5 is a diagram of an experimental result showing variation of a Q and a γ with respect to the change of an aperture length of the electrode fingers.

1: crystal substrate, 4, 5: inter-digital transducer electrodes

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Translation of the Drawings

第１図：Fig. 1

第２図：Fig. 2

水晶カット角：CRYSTAL CUT ANGLE

電極対数：NUMBER OF PAIRS OF ELECTRODES

波長：WAVELENGTH

電極指交叉長：APERTURE LENGTH OF ELECTRODE FINGERS

第３図：Fig. 3

副共振レベル：SUB-RESONANCE LEVEL

副共振：SUB-RESONANCE

第５図：Fig. 5

副共振レベル：SUB-RESONANCE LEVEL

副：SUB

第５図：Fig. 5

Amendment

January 29. 1982

Director General of the Patent Office, Esq.

1. Case Identification

1981 Patent Application No. 131739

2. Title of the Invention: Shear Wave Resonator

3. Person Filing Amendment

Relationship to Case: Patent Applicant

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4. Date of Amendment Directive: January 5, 1982

5. Number of Inventions Added by the Amendment: Nil

6. Parts Amended: Drawings

7. Content of the Amendment: as per Enclosed Attachment

Translation of the Drawings in the Amendment

第３図：Fig. 3

副共振レベル：SUB-RESONANCE LEVEL

副共振：SUB-RESONANCE

第４図：Fig. 4

副共振レベル：SUB-RESONANCE LEVEL

副：SUB

第５図：Fig. 5